Hygroscopic Properties of Nigerian Wood Brachystegla and Experimental Determination of Shrinkage Characteristics

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Abstract. The current research is dedicated to the experimental determination of shrinkage characteristics of *Brachystegia nigeria* wood on its linear, volumetric, and coefficient values with the hope of ascertaining its utilization potential as timber. Two study locations were randomly selected from defined vegetation zones of the *guinea savannah* for the study. These are Anambra *(guinea savanna)* and Oyo (rain forest). Twenty tree samples of *Brachystegia nigeria* were randomly selected and felled from which sixty wood specimens were extracted and prepared using Romanian standard for the research. The analysis of variance (ANOVA) was used to experiment demonstrated that the tree species has an average tangential linear shrinkage of 10.74%, radial linear shrinkage of 4.24%, longitudinal linear shrinkage of 1.10% and volumetric shrinkage of 18.10%. The coefficients of tangential, radial and longitudinal shrinkage were 0.00662, 0.00315 and 0.00060 respectively. The analysis of variance revealed insignificant differences of shrinkage between the two vegetation zones, the sampled trees as well as between the trunk sections. Since the shrinkage value of *Brachystegia nigeria* wood compare favorably with some local wood species, used for timber, *Brachystegic nigeria* wood could be considered suitable for timber production.

Key words: *Brachystegia nigeria,* Coefficient shrinkage, Linear shrinkage, Vegetation zones, Volumetric shrinkage.

Introduction

Wood is a hard fibrous tissue found in many trees. It has been used for hundreds of thousands of years for fuel and as a construction material. Wood is a hygroscopic substance; that is, it has or affinity for water in both liquid and vapor form. This ability to absorb or to loose water is dependent on the temperature and the humidity of the surrounding atmosphere. As a consequence, the amount of moisture in wood fluctuates with changes in the atmospheric conditions. All physical and mechanical properties of wood are greatly affected by the fluctionate of the quantity of water present in wood. In using wood as a raw material is essential to be able to evaluate its moisture level, and to understand where the moisture is located and how it moves through the wood.

Shrinkage and swelling may occur in wood when the moisture content is changed (Desch, 1992: 46). Shrinkage occurs as moisture content decreases below the fibre saturation point while swelling takes place when it increases above the fibre saturation point. Volume change is not equal in all directions. The greatest dimensional change occurs in a direction tangential to the growth rings. Shrinkage from the pith out wards, or radially, is usually considerably less than tangential shrinkage, while longitudinal (along the grain) shrinkage is so slight as to be usually neglected. The longitudinal shrinkage is 0.1% to 0.3%, in contrast to trans versa shrinkage, which is 2% to 10%. Tangential shrinkage is often about twice as great as in the radial direction, although in some species it is as much as five times as great. The shrinkage is about 5% to 10% in the tangential direction and about 2% to 6%in the radial direction (Greenwood, 1999: 241-242). As with all wood properties, shrinkage is highly anisotropic. Tangential shrinkage (occurring tangential to the rings) is 1.5 to 2.5 times greater than radial shrinkage (occurring along the radius of the rings). Tangential shrinkage from green to dry ranges from 6% to 13% depending on the species, radial shrinkage ranges from 2% to 8%. Longitudinal shrinkage (occurring in the direction of the tree growth is usually very small, 0.1% to 1.5% (Akpan et al., 1999: 6-11). Addition of water or other polar liquids to the cell wall substance causes the microfibrillar net to expand in proportion to the amount of liquid which has been added. This continues until the fiber saturation point is reached. Further addition of water to the wood produces no change in volume of the wall substance. Conversely the removal of moisture from the cell wall below the fiber saturation point causes the wood to shrink. Such dimensional changes are traditionally expressed as a percentage of the maximum dimension of the wood, and since the green size is a condition at which no reduction in dimension has yet occurred, the shrinkage is expressed as a percentage of the green volume (Rowell and Banks, 1985: 24). According to J.A. Panshin and C. Dezeeuw, wood shrinkage in general does not begin until the fiber saturation point (25 – 30%) is reached (Panshin and Dezeeuw 1980: 121-127). The tangential shrinkage is about twice as large as the radial, at the same moisture content. The volumetric shrinkage is roughly the sum of the tangential and radial shrinkages, since the longitudinal shrinkage from the green to even dry condition is almost negligible (Akpan et al., 1999: 6-11).

The wood species under study is *Brachystegia nigeria*, which belongs to the meliaceae family. Its local name in Nigeria is Achi. This wood species is easily adaptable to the local environmental conditions of Nigeria. Researches carried out by S. A. Radwanski in Sokoto showed that *Brachystegia nigeria* is a fast growing tree that can be established without irrigation in many arid regions (Radwanski, 1969: 507-511). It grows well on poor shallow story or sandy soils. However, there has been no information on its wood chacteristics, particularly shrinkage qualities, in relation to utilization as timber. The objective of this paper is to determine the shrinkage characteristics of Brachystegia Nigeria wood for timber utilization in eastern Nigeria.

Materials and Methods

Two vegetation zones of eastern Nigeria vizi Guinea savanna and rain forest were chosen for the study. The representative randomly selected study locations in each of these zones are Anambra, Guinea savanna Oyo, rainforest. From each of these study locations twenty (20) matured *Brachystegia nigeria* trees were chosen by block random sampling from free area, using merchantable diameter of at least 60cm as basis for acceptance. Out of this number, 10 tree samples were randomly selected and felled. Thus a total of 20 *Brachystegia nigeria* tree samples were isolated from the two study locations for the research. In determining the ages of the felled trees, their growth rings were counted to ensure that the trees fell into the acceptable merchantable ages of 20 years and above. Thereafter, each felled tree from the two vegetation zones of eastern Nigeria was cross cut into three sections from base to top, which is bottom, middle and top in line with the conventional sampling strategy of 0%, 20% and 40% of the total three heights. Thus twenty test pieces were obtained from defects free areas of the trees and prepared according to STAS 6085%:72. Accordingly, the wood species were cut to sizeable samples of 100mm x 60mm x 40m for the purpose of oven drying to constant weights. After wards, each specimen was extracted from the seasoned samples by cutting to a standard dimension of 30mm x 200mm x 20mm. The specimens were sectioned such that the wood rays in the radial axis were parallel to the fibers in the tangential and longitudinal axes.

Thereafter, each felled tree from the two vegetation zones of eastern Nigeria was cross cut into three sections from base to top, that is, bottom, muddle and top in line with the conventional sampling strategy of 0%, 20% and 40% of the total tree height. Thus sixty test pieces were obtained from defects free areas of the trees and prepared according to STAS 6085:72. Accordingly the wood species were cut to sizeable samples of 100mm x 60mm x 40mm for the purpose of oven drying to constant weights. After wards, each specimen was extracted from the seasoned samples by cutting to a standard dimension of 30mm x 20mm x 20mm. The specimens were sectioned such that the wood rays in the radial axis were parallel to the fibers in the tangential and longitudinal axes.

Thereafter, the test pieces were completely immersed in water for 30 minutes. Subsequently, at regular intervals of 15 minutes, their moisture contents were measured with the moisture meter until an initial (green) moisture content of at least 30% was attained for each test piece. This is the fiber saturation point (FSP) of wood, at which shrinkage begins to occur. Immediately by means of a micrometer, screwguage the initial (maximum) dimensions of the three assay-metrical axes (tangential, radial and longitudinal) of the specimens were taken. The wood specimen dried at a temperature of 103^{o}C ± 2^{o}C for 24 hours STAS 6085:72) after the wood samples have dried at intervals of 15 minutes, the specimen was weighed with the electronic weighing balance, until a constant weight was obtained for each of them. Their final (oven dry) moisture contents were also taken similarly, the final (minimum) dimensions of the three axes of the specimens were recorded using the micrometer screw gauge. On the bases of these dimensions, tangential, radial and longitudinal linear shrinkage of the sixty wood specimens were calculated with the respective relationships.

$$TgS = \frac{Dt - dt \times 100\%}{Dt}$$

$$RdS = \frac{Dr - dr \times 100\%}{Dr}$$

$$LgS = \frac{Dl - dl \times 100\%}{Dl}$$

Where

TgS: Tangential linear shrinkage (%)

RdS: Radial linear shrinkage (%)

LgS: Longitudinal linear shrinkage (%)

Dt: Initial dimension (mm) along the tangential axis at gren moisture content of ≥ 30%.

Dr: Initial dimension (mm) along the radial axis at green moisture content of ≥ 30%.

Dl: Initial dimension (mm) along the longitudinal axis at a green moisture content of ≥ 30%.

dt: Final dimension (mm) along the tangential axis at oven dry moisture content of << 30%.

dr. Final dimension (mm) along the radial axis at oven dry moisture content of << 30%.

dl: Final dimension (mm) along the longitudinal axis at oven dry moisture content of << 30%.

Their mean values were obtained as the linear shrinkages of the three asymmetrical axes of the wood species under study. In the same vein, volumetric shrinkage (Vs) of each of the 60 wood specimens was computed with the relationship:

$$Vs = \frac{100 - (100 - LgS)(100 - RdS)(100 - TgS)\%}{10^4}$$

The mean values were also obtained. With the zones as well as the tree samples, and their respective sections being the sources of variation, and volumetric shrinkage, as parameter, the analysis of variance (ANOVA) was used to analyze the obtained data, by testing the level of significance of shrinkage between the different vegetation zones, and also between the sampled trees and their respective sections. Relationship between volumetric shrinkage and drying out to oven dry moisture content in the two vegetation zones was also examined. To calculate the coefficients of tangential (dt), radial (dr) and longitudinal shrinkages respectively, the following equations were used:

$$\alpha t = \frac{Dt - dt}{Dt\,(Mg - Md)}$$

$$\alpha r = \frac{Dr - dr}{Dr\,(Mg - Md)}$$

$$\alpha l = \frac{Dl - dl}{Dl\,(Mg - Ml)}$$

Where;
Mg: Green moisture content %
Md: Oven dry moisture content %

Results and Discussion

Averagely green moisture contents 31.80 in Guinea savanna and 31.40, 36 in rainforest, the mean initial dimensions of the specimens are 20.40mm (Guinea Savanna) and 20.41 mm (rain forest) along the tangential axis (Dt) the mean initial dimensions of the wood specimens along the radial axes (Dr) in the Guinea and rainforest are 21.20mm and 21.22mm respectively. Also the longitudinal axes (Dl) of the specimens have mean initial dimensions of 30.20mm in Guinea savanna and 30.22 mm in rain forest at the same green moisture contents.

At oven dry moisture contents of 13.44% in Guinea and 12.53 in rain forest, the average final dimensions of the test pieces along the tangential axes (dt) are 18.60mm, 18.57mm respectively. The average dimensions of the wood samples along the radial axes (dr) in the Guinea savannah and rain forest are 19.82mm and 19.83mm. Longitudinally (dl), the mean final dimension of the specimens is 29.85 mm in each of the two zones.

Accordingly, linear shrinkage along the tangential axes in the Guinea savanna range from 11.30% to 14.06% with a mean of 12.63%. Similarly, linear shrinkage along the tangential axes in the rain forest range from 12.06% to 13.71% (mean of 12.84%). In the same way, the linear shrinkage along the radial axes in the Guinea savanna range from 5.27% to 7.01% (mean of 6.22%) and those of the rain forest range from 5.27% to 7.03% having a mean of 6.40%. Along the longitudinal axes, in the Guinea, savanna, the linear shrinkage ranges from 1.00% to 1.31% with an average of 1.31%. White the longitudinal linear shrinkage in the rain forest range from 0.64 to 1.33, having a mean of 1.16%.

In the tangential axis, the coefficients of linear shrinkage vary from 0.00577 to 0.00767 in Guinea savanna, and 0.00592 to 0.00767 in rainforest. The mean coefficient of tangential shrinkage in Guinea savanna is 0.00672 while that of 8 rain forest is 0.00666. The overall mean coefficient of tangential axis across the study locations is 0.0673. Along the radial direction, the coefficients of linear shrinkage in Guinea savanna vary from 0.00262 to 0.00382 and 0.00270 to 0.00391 in rain forest. The mean coefficient of radial shrinkage in Guinea savanna is 0.00332 while that of rain forest is 0.00326. The overall mean, coefficient of radial axis across the study locations is 0.00338. In the longitudinal axis, the coefficients of linear shrinkage vary from 0.00044 to 0.00084 in rain forest. The mean coefficient of longitudinal shrinkage in Guinea Savanna is 0.00053 while that of rain forest is 0.00057. The overall mean coefficient of longitudinal axis across the study locations is 0.00060.

The volumetric shrinkage in Guinea Savanna ranges from 10.20% to 11.40% with a mean of 11.10%. In the rain forest, it ranges from 10.21% to 11.42% having a mean of 10.90%. The overall mean volumetric shrinkage across the two zones is 11.10%. Also the oven dry moisture contents of the wood specimens range from 6.52% to 8.65%, with an average of 7.81% in Guinea savanna. The oven dry moisture contents of the wood specimen range from 6.10% to 8.42%, in rain forest. The mean oven dry moisture content in rain forest is 7.65%. Table 1 contains volumetric shrinkage of *Brachystegia nigeria* wood. Volumetric shrinkage contains the results of the ANOVA of *Brachystegia nigeria* shrinkage.

Table 1. Volumetric shrinkage of *Brachystegia nigeria* in the two vegetation zones of Eastern Nigeria

Tree	**Volumetric shrinkage of *Brachystegia nigeria* %**								
	Guinea savanna wood specimen				**Rain forest wood specimen**				
	1A	2A	3A	Mean shrinkage value	1X	2X	3X	Mean shrinkage value	Overall shrinkage value
1	10.40	10.42	10.18	10.20	10.22	10.23	10.21	10.22	10.21
2	10.21	10.20	10.22	10.21	10.20	10.22	10.20	10.21	10.21
3	11.43	11.40	11.37	11.40	11.42	11.39	11.45	11.42	11.40
4	10.82	10.85	11.87	10.85	10.95	10.92	10.98	10.95	10.90
5	11.09	11.10	11.11	11.10	11.06	11.08	11.06	11.07	11.09
6	10.95	10.95	10.90	10.90	10.68	10.72	10.10	10.70	10.80
7	11.27	11.24	11.22	11.25	11.23	11.24	19.21	11.23	11.24
8	11.25	11.22	11.25	11.25	11.22	11.20	11.20	11.21	11.23
9	11.28	11.27	11.29	11.28	11.34	11.32	11.30	11.32	11.30
10	11.29	11.30	11.28	11.29	10.30	10.39	10.32	10.31	10.30
Mean	11.00	11.10	11.10	11.10	10.89	10.91	10.90	10.90	11.10

*Note: 1: bottom, 2: middle, 3: top

Brachystegia nigeria at an average volumetric shrinkage of 11.00%, even though compared favorably with some shrinkage values of some locally used timber, is quite low when compared with majority of the Nigerian timber. Examples of locally used timber that *Brachystegia nigeria* shrinkage does not compared favorably with are Uapaia guineensis (19.9° stronmbosia pustulata (19.7%), sterculia rhinopetala (20.9%), Distemonanthus benthamianus (20.6%) and Lophira alala (19.8%) (Ghelmeziu, 1981: 323). Those commonly used timber that Brachystegia shrinkage compared favorably with include Pericopsis elata (10.0%), Terminalla salperba (10.3%) and whaya Ivorensis (9.1%), Triplochiton scleroxy lon (9.7%), Mansonia altissima (10.3%), and Afzelia Africana (9.8%). Others are ceibapentandra (10.4%) Mitragyna ciliate (13.1%), Tectona grandis (15.0%), Gossweilerodendron balsamiferum (7.6%), Pycnancinthus angolensis (14.5%), chlorophora eoccelsa (9.4%), Entandrophragma cylindricum (12.6%), and Eribroma oblonga (18.3%) (Akpan et al., 1999: 6-11). However, the Nigerian Standard Code of Practice specifies that all woods must be seasoned to equilibrium moisture contents of the surrounding environment before they are subjected to services conditions (Nigerian Standard Code of Practice, 1973).

The purpose being to subject timber to the same moisture conditions sit is likely to attain in service. In the case of *Brachystegia nigeria*, the air seasoning technique may be suitable to minimize any defect that could arise from excessive drying stresses and associated shrinkage. The tangential shrinkage at 10.74% is about twice as large as the radial shrinkage with a value of 42.4% at the same moisture content of 13.05%. Also observed from the shrinkage results is the fact that the volumetric shrinkage is approximately the sum of the tangential and radial shrinkages, since the longitudinal shrinkage from green to oven dry condition is almost negligible. It was also observed that coefficient of tangential shrinkage at 0.00662 was almost twice that of radial shrinkage at 0.00315 at oven dry moisture content of 13.05%. This agreed with the principle that the tangential shrinkage is higher than those of the radial and longitudinal shrinkages (Suchsland. and Woodson, 1986: 163-171), (Harris et al., 1985: 3-52), (Kellogg and Wangaard, 1989: 42-56), (Akpan et al., 1999: 6-11). Also discovered in the course of the *Brachystegia nigeria* shrinkage experiment is the concept that shrinkage of the wood samples did not begin until the fiber Saturation point was attained by R. Wagenfuhr and A. Steiger (Wagenfuhr and Steiger, 1972: 77-89). This observation also agrees with the works of J.A. Panshin and C. Dezeeuw (Panshin and Dezeeuw 1980: 121-127) and M. Akpan et al. (Akpan et al., 1999: 6-11) that shrinkage only occurs at moisture contents equal to fiber saturation point. With regard to the relationship between moisture content and volumetric shrinkage, it was found that shrinkage did not occur when the wood samples were fully saturated with water. However, as the moisture content in the wood samples reduces from green to dry condition, the volumetric shrinkage increases. This, concept is explained by the fact that wood begins to shrink only when it attains fiber saturation point and the more moisture that leaves the wood, the higher the volume of shrinkage. The shrinkage finally cecoses, when the wood is completely dried. These findings agree with similar works conducted by R.M. Rowell and W.B. Banks (Rowell and Banks, 1985: 24), M. Akpan et al. (Akpan et al., 1999: 6-11), as well as O. Suchsland. and G.E. Woodson (Suchsland. and Woodson, 1986: 163-171).

It is important to note that this low shrinkage value of *Brachystegia nigeria* made the tree species to be particularly application as timber for interior and external utilization outside. Because of the low shrinkage values of *Brachyslegia nigeria*, it does not exhibit considerable shrinkage that might lead to warping with a corresponding high degree of wastage. The results of the analysis of various (ANOVA) reveals that none of the two different vegetation zones showed significant difference in shrinkage values at 5% probability level ($P < 0.05$). In the same way, significant difference in shrinkage was not attained between the *Brachystegia nigeria* tree samples and the sections at 5% level of probability ($P < 0.05$) (Table 2).

Table 2. Results of ANOVA for *Brachystegia nigeria* shrinkage in the two vegetation zones

SV	Ss	Df	Ms	F	P - value
Trees	3.48864148	12	0.29918868	1.45^{ns}	0.0504
Vegetation zones	0.28864148	2	0.09432074	0.70^{ns}	0.2684
Tree section	0.35758370	2	0.27879185	1.01^{ns}	
Error	20.1814711	82			
Total	24.716338	100			

*Note: ns - not significant ($P < 0.05$)

Conclusion

Brachystegia nigeria has a relatively low volumetric shrinkage. It however, compares favorably with shrinkage of some locally used wood species for timber production and therefore could be considered suitable for timber utilization. On account of moisture loss along tangential axes, of the wood which is almost twice that of the radial axes, the tangential axes could be treated by applying a thick coat of oil paint to prevent too much loss of moisture, thus reducing the volume of shrinkage. Wooden cleats can also be nailed on the tangential axes of the wood to seal the end green from excess moisture loss.

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